ERDC/GSL TR-04-11

Geotechnical and Structures Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Vehicle Capacity API for Transportation Infrastructure Network Builder (TINet)

George B. McKinley

September 2004

ERDC/GSL TR-04-11
September 2004

Vehicle Capacity API for Transportation Infrastructure Network Builder (TINet)

George B. McKinley

Geotechnical and Structures Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for Military Surface Deployment and Distribution Command
Transportation Engineering Agency
720 Thimble Shoals Blvd., Ste. 130
Newport News, VA 23606-4537

ABSTRACT: This report presents the methodology and results of a process that categorizes the transportation network and the derivation of the associated pass rates for convoys of vehicles. The first part of the report describes the process of deriving the pass rates for vehicle convoys. The second part describes the development of an NT-automated protocol interface (API) to determine the highway throughput capacity (vehicles per day) of a given road link based on its Transportation Infrastructure Network Builder (TINet) attributes and the Transportation Analysis Reports Generator (TARGET) movement requirements of the force being modeled. The development effort covers these seven U.S. Army Training and Doctrine Command Table of Organization and Equipment forces: separate infantry brigade, airborne division, air assault division, light infantry division, mechanized infantry division (MEC), armor division, and Interim Brigade Combat Team. Throughput capacity as a function of road link attributes is computed for these seven hard-coded force types. The code will also compute a capacity for a TARGET-generated equipment list, which does not match one of the pre-computed seven units.

Contents

Preface

The study reported herein was conducted by members of the staff of the U.S. Army Engineer Research and Development Center (ERDC), Geotechnical and Structures Laboratory (GSL), Engineering Systems and Materials Division (ESMD), Mobility Systems Branch (MSB), Vicksburg, MS. The work was conducted under Work Item Codes 007XAL, "Force-Based Throughput Capacity," and 008PQ6, "Development of Force-Based Throughput Capacity Code for TINet." Sponsor for the projects was the Military Surface Deployment and Distribution Command, Transportation Engineering Agency. The work was conducted between June 2001 and June 2004.

The study was conducted under the general supervision of Dr. David W. Pittman, Acting Director, GSL; Dr. Albert J. Bush III, Chief, ESMD; Dr. David A. Horner, Chief, MSB; and Dr. William E. Willoughby, Acting Chief, MSB. The overall development was accomplished by Messrs. George B. McKinley, E. Alex Baylot, and Burhman Q. Gates and Ms. Flossie N. Ponder, MSB. The report was written by Mr. McKinley.

COL James R. Rowan, EN, was Commander and Executive Director of ERDC, and Dr. James R. Houston was Director.

1 Introduction

Background

The Transportation Infrastructure Network Builder (TINet) enables non-technical analysts to build the all-source geographic information system (GIS) road, rail, and waterway network databases needed for the Military Surface Deployment and Distribution Command Transportation Engineering Agency's (SDDCTEA) transportation models and simulations.

For the past 10 years, the Modernized Integrated Database (MIDB) has been the agency's primary source (hard and most recently soft copy) of highway throughput capacity. Defense Intelligence Agency (DIA) analysts calculated these values using DIA's methodology presented in their document entitled "Highway Resupply Methodology" (DIA 1990). The current MIDB version does not have the capability to export highway attributes such as throughput capacity. To obtain the required data, SDDCTEA must now develop the capability in TINet to calculate highway throughput capacity based on the attributes contained in the TINet road file structure. While DIA's Highway Resupply Methodology is available in a variety of automated forms, it is based on five-ton cargo trucks and other assumed factors that are not representative of today's modern military forces and its output is short-tons-per-day. SDDCTEA's models and simulations (M&S) perform force-based line-item-number (LIN) level analyses and require highway throughput capacity based on highway link attributes and the transportability characteristics of the equipment that compose the force being modeled. SDDCTEA uses the Transportability Analysis Reports Generator (TARGET) to detail unit movement requirements at the LIN level of detail.

The Mobility Systems Branch (MSB) has a long history of providing Tactical Decision Aids (TDA) for military planning systems and ground movement algorithms for M&S. These TDA and M&S algorithms are based on the NATO Reference Mobility Model Edition II (NRMMII), which is an Army Model and Simulation Office (AMSO) standard for ground vehicle movement. Characterization of network throughput in a theater of war is a challenge within M&S. This concept is becoming increasingly important in light of the need to conduct analysis in support of achieving the Chief of Staff of the Army's vision of a highly deployable, more agile, lethal, and tactically mobile force. Issues involving complexity, run-time, fidelity, and data descriptions must be considered in developing procedures to capture the capacities, or throughput potential, associated with routes through an area of operation. The MSB has

developed a methodology to describe the environment, derive capacities, and aggregate theater networks in support of deployment, sustainment, and movement operations via M&S for planning and analysis.

Purpose and Scope

The purpose of this report is to present the methodology and results of a process that categorizes the transportation network and the derivation of the associated pass rates for convoys of vehicles. The first part of the report describes the process of deriving the pass rates for vehicle convoys. The second part describes the development of an NT-automated protocol interface (API) to determine the highway throughput capacity (vehicles per day) of a given road link based on its TINet attributes and the TARGET-generated movement requirements of the force being modeled. The development effort covers these seven TRADOC TOE forces: separate infantry brigade (SIB), airborne division (ABN), air assault division (AAS), light infantry division (LID), mechanized infantry division (MEC), armor division (ARM), and Interim Brigade Combat Team (IBCT). Throughput capacity as a function of road link attributes is computed for these seven hard-coded force types. The code will also compute a capacity for a TARGET-generated equipment list, which does not match one of the pre-computed seven units.

2 Derivation of Pass Rates

Profile Generation

Synthetic fractal elevation profiles were created to represent plains, hills, and mountains. Plains are flat to rolling areas with comparatively little change in elevation between high and low places (Headquarters, Department of the Army 1972). Hills are characterized by moderately high local relief of limited extent with steep slopes, and small summit areas, which rise above the surrounding area. Mountains have high elevations, steep slopes, and small summit areas with local relief greater than 610 m (2,000 ft). The profiles were placed in one of the three landform types based on the maximum slope and the local relief. The slope was computed by taking the rise over the run between each of the postings in the profile. The local relief was defined as the difference between the highest and lowest elevation in a 100-km stretch of elevation profile. The criteria used to classify terrain are shown in Table 1.

Table 1
Landform Classification Criteria

Landform Type	Maximum Local Relief, ft[1]	Maximum Slope, %
Plains	<500	7
Hills	500 – 2,000	10
Mountains	>2,000	>10

[1] To convert feet to meters, multiply by 0.3048.

The fractal profiles were created using the midpoint displacement method (Barnsley et al. 1988). This algorithm is as follows:

```
ioff := maxdim/2;  d := maxdim;
for j := 1 to maxlvl do
begin
   delta := Sigma * 0.5**(j * H) * sqrt(1.0 – 2.0**(2.0 * H – 2));
   for ny := ioff to maxdim by d do
   begin
      y[ny] := (y[ny + ioff] + y[ny – ioff])/2 + delta * Rand(Seed);
   end;
   d := d/2;
   ioff := ioff/2;
end;
```

For this study, *maxlvl* was set to 13, which yielded profiles consisting of 8193 ($2^{13}+1$) evenly spaced elevation postings. The variable *maxdim* would be 8192 (2^{13}) because the initial elevation posting would be denoted by 0. *Rand* is a function that returns a random number from a Gaussian distribution. Postings were generated over a 300-km traverse. Profiles were created using various values for *Sigma* for fractal dimensions falling between 1.01 and 1.46. *Sigma* is the initial standard deviation. It controls the amount of overall elevation change that is produced in the resulting profile. The fractal dimension, in the midpoint displacement algorithm, is given by 2-H. Appendix A lists the fractal dimensions and the corresponding values of *Sigma* for the profiles selected to represent a statistically significant sample size of 25 per landform category. The procedure for screening the acceptability of profiles involved generating 45 raw profiles for each landform. The criteria for topology category (plains, hills and mountains) were applied in order to choose the 25 statistically significant profiles for each topology. The criteria used were maximum local relief and maximum slope as shown in Table 1. This resulted in synthetic profiles for plains, hills, and mountains, generated from a set of raw profiles. Examples of profiles that represent plains, hills, and mountains are shown in Figures 1 through 3.

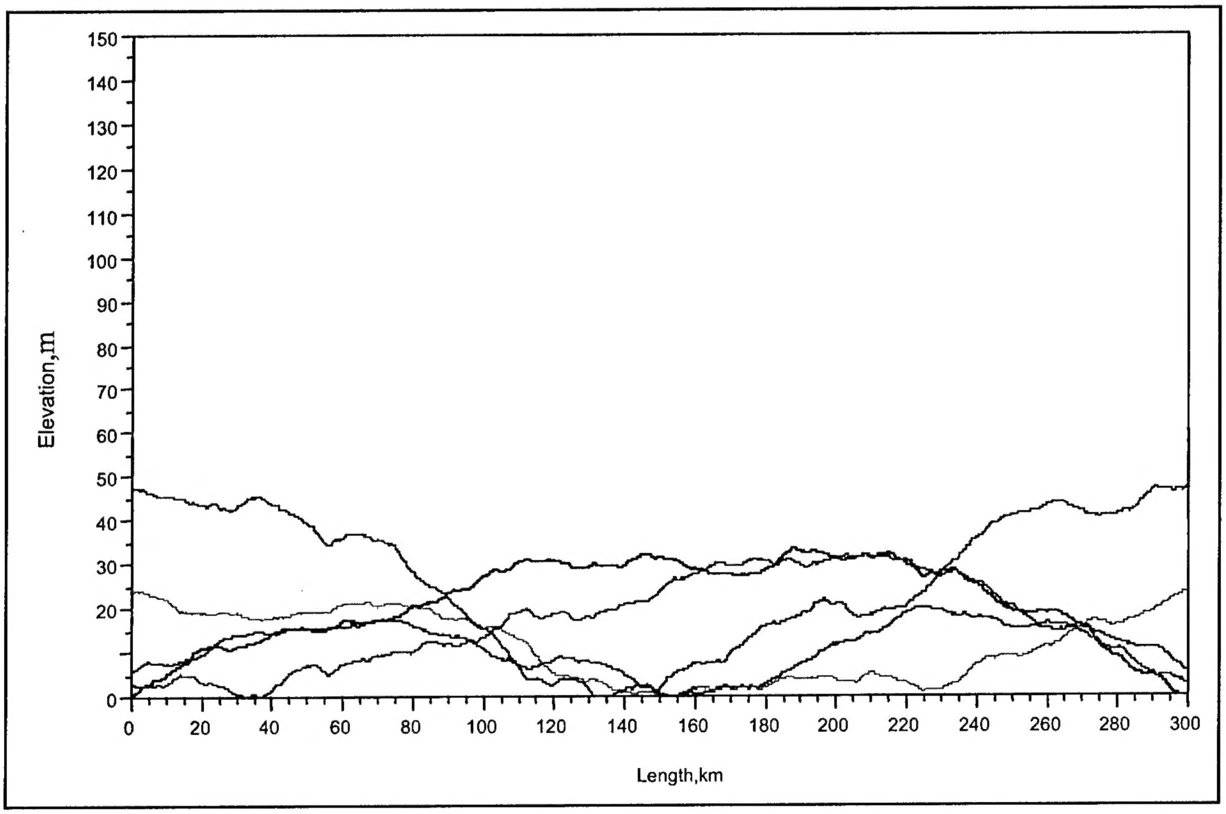

Figure 1. Example profiles representing plains

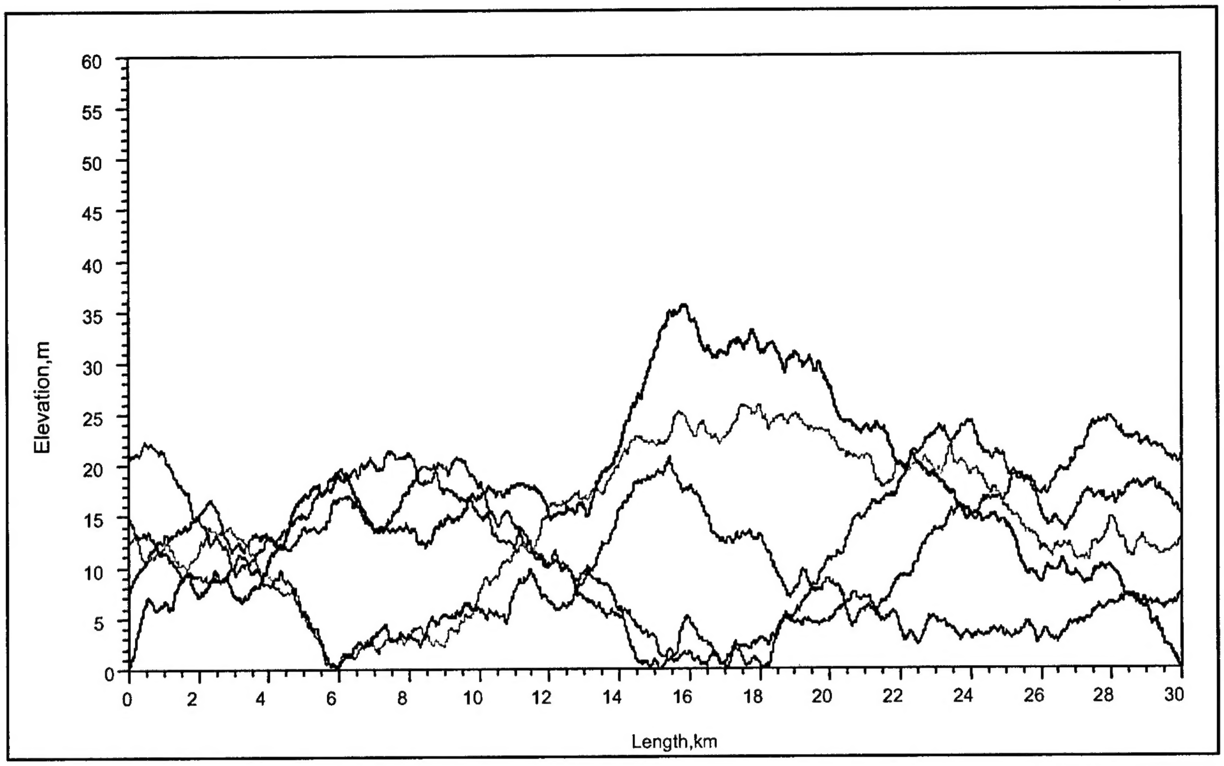

Figure 2. Example profiles representing hills

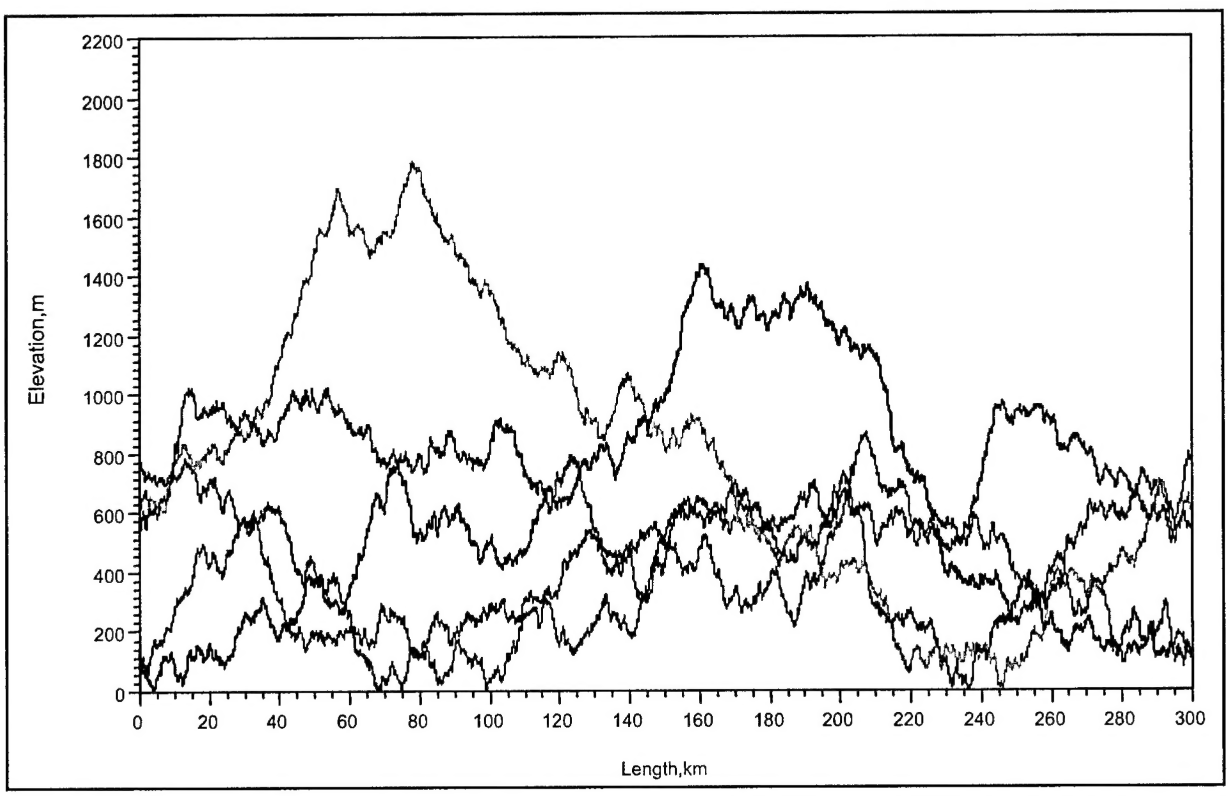

Figure 3. Example profiles representing mountains

Profile Conversion for Use with Mobility Models

The fractal elevation profiles were converted to road files in the proper format to be used as input to NRMMII. The NRMMII (Ahlvin and Haley 1992) is a comprehensive analytical model designed to evaluate objectively the on- and off-road mobility of vehicles by means of digital computer simulation. This model is the AMSO standard for ground vehicle movement. The NRMMII road database is divided into homogeneous units, each of which should be nominally uniform with respect to values pertinent to mobility (Mason et al. 1985).

Separate road files were created for each profile to represent the road types of super highways/primaries, secondary roads, and trails. A primary road has two or more lanes consisting of an all-weather hard surface with good driving visibility used for heavy and high-density traffic. These roads have a minimum lane width of 2.74 m (9 ft). A super highway has four or more lanes with limited access to and from other roads. A secondary road is an all-weather road with two lanes, maintained, with a hard or loose surface (paved, crushed rock, gravel) and intended for medium-weight, low-density traffic. This road has a minimum lane width of 2.44 m (8 ft). A trail is a one-lane, dry-weather, unimproved, loose-surfaced road intended for low-density traffic. Trails have a minimum lane width of 2.44 m (8 ft) with no large obstacles (boulders, logs, stumps) and include gravel- and dirt-surfaced roads.

The major road difference is the maximum slope allowed for each road type, as a result of the fact that more grading would be done to alleviate steep slopes on a super highway/primary as opposed to a secondary road or trail. Flat sections of road with curves were introduced if the road had the same slope direction (uphill or downhill) for a distance greater than a designated critical distance (0.402 km (0.25 mile)) (Wright and Ashford 1982). This was done to model the effects of switchbacks in mountainous terrain. Table 2 illustrates the factors associated with each terrain/road combination. Surface roughness in the NRMMII road terrain files was purposely set to 0.1 rms, so that ride quality would not factor into the final results. The trails were modeled as hard-surfaced with soil strengths of 300 Rating Cone Index (RCI) and a Universal Soil Classification System (USCS) type of SM.

Table 2
Slopes and Curvatures for Each Terrain/Road Combination

Terrain Type	Super Highways and Primary Roads		Secondary Roads		Trails	
	Maximum Slope, %	Radius of Curvature ft[1]	Maximum Slope, %	Radius of Curvature ft	Maximum Slope, %	Radius of Curvature ft
Plains	3	1,348	6	509	7	273
Hills	4	1,206	7	468	10	249
Mountains	6	1,091	10	432	15	229

[1] To convert feet to meters, multiply by 0.3048.

Mobility Models

The NRMMII predicts the maximum attainable safe speed of a vehicle for each terrain unit by treating each unit as if it were of sufficient length to obtain steady-state speed.[1] For its database, the NRMMII requires quantitative input descriptions of terrain, vehicle, and driver attributes. Road terrain attributes were discussed previously. NRMMII was used with the resulting road terrain files for the M1084, M985, and M917, which were selected as representative of high-, medium-, and low-mobility wheeled vehicles. The M1084 with the M1095 trailer, the M985 with the M989 trailer, and the M911 with the M747 trailer were chosen to represent high-, medium-, and low-mobility wheeled vehicles towing a loaded trailer. The M1A1 tank, the M88A1 recovery vehicle, and the Armored Vehicle Launched Bridge (AVLB) were selected to represent high-, medium-, and low-mobility tracked vehicles. The M113A2 and the LAV3 were chosen to represent tracked and wheeled amphibious vehicles. Some critical vehicle parameters for these vehicles are shown in Table 3.

Table 3
Characteristics of Study Vehicles

Vehicle Name	Type	Mobility Class	Vehicle Weight, lb[1]	Total Length, ft[2]	Horsepower per Ton[3]
M1084	Wheeled	High	34,090	25.5	17.0
M985	Wheeled	Medium	60,250	33.4	13.4
M917	Wheeled	Low	72,900	29.2	11.0
M1084/M1095	Towed	High	55,108	44.7	10.5
M985/M989	Towed	Medium	90,820	59.2	8.9
M911/M747	Towed	Low	181,000	65.4	4.9
M1A1	Tracked	High	127,451	26.0	23.5
M88A1	Tracked	Medium	112,000	27.1	13.4
AVLB	Tracked	Low	123,000	37.0	12.2
LAV3	Wheeled	Amphibious	39,412	22.7	15.8
M113A2	Tracked	Amphibious	25,000	16.0	17.0

[1] To convert pounds to kilograms, multiply by 0.4536.
[2] To convert feet to meters, multiply by 0.3048.
[3]. To convert horsepower per ton to watts per kilonewton, multiply by 83.82.

Driver attributes in the NRMMII characterize the driver according to his ability to perceive and react to visual stimuli affecting his behavior as a vehicle controller and his limiting tolerances to shock and vibration. For the particular surface material of interest, values of drawbar pull and rolling resistance, as coefficients, are obtained for the given vehicle operating straight-line on the surface. From these coefficients, a tractive force versus speed curve is developed. Various speeds are then computed as limited by various resistances; ride and shock (absorbed power and peak acceleration); visibility and braking; and road curvature. The least of these speeds is assigned as the operating speed for that terrain unit. Speed predictions for up-slope, down-slope, and level

[1] Post-processors are available to use internal acceleration/deceleration routines to adjust the speeds between units based on the predicted time required to cross each unit for short traverse distances.

ground are stored to allow the selection of the appropriate prediction by the Combat Maneuver Model (CMM).

The CMM (McKinley et al. 1993) computes the time required for a group of vehicles to traverse a series of terrain units. The vehicles must travel in one of four basic formations: column, bounding over-watch, combat lines, and parallel columns. The minimum and maximum following distances for vehicles within a column formation, in addition to a maximum allowed speed, are input to the routine, thus allowing the modeling of both open and closed column formations (Headquarters, Department of the Army 1984). The CMM was used in this study with homogeneous columns made up of each of the vehicles. The CMM was run for four visibility conditions as shown in Table 4. The CMM models the column at a specified time interval (5 sec in this case). The vehicles are allowed to move along the traverse at their NRMMII-predicted speed or the allowed maximum march rate as shown in Table 4 for the time interval. If vehicle A gets too close (less than the minimum spacing) to the preceding vehicle B, then vehicle A would be required to travel at a slower pace over the time interval to maintain the column's integrity. If vehicle A gets too far behind (more than the maximum spacing) the preceding vehicle B, then vehicle B would be required to travel at a slower pace over the time interval to maintain the column's integrity. The time interval at which the first vehicle enters a terrain segment and the time when the last vehicle exits a terrain segment are saved. The difference between these times is termed the pass time for the column.

Table 4
Column Parameters for Visibility Conditions

Visibility	Recognition Distance, ft[1]	Spacing Range, m	Maximum Speed kph	Formation
Unlimited	300	50 – 100	64	Open
Fog	50	50 – 100	64	Open
Limited	30	25 – 50	24	Closed
Blackout	10	20 – 25	8	Closed

[1] To convert feet to meters, multiply by 0.3048.

Results

Convoy movement was simulated for each of the vehicles in 25-vehicle columns traversing each of the representative profiles. The average of the pass times for all the profiles representing a terrain type in a given weather/visibility condition was used as the capacity for that vehicle. Appendix B lists the computed capacities for all vehicle, road type, terrain, weather, and visibility combinations. For a point of reference, the results for the M923 and the M923 towing the M1061 trailer were compared to the capacities presented by the Defense Intelligence Agency (DIA) in their document (DIA 1990). The 5-ton M923 was selected because the DIA methodology was based on a medium-sized cargo truck carrying a payload of 5 metric tons. The M923 was a 5-ton truck in operation during 1990 when the DIA methodology was published and some of its pertinent parameters are shown in Table 5.

Table 5 **Characteristics of M923 and M923 Towing M1061 Trailer**			
Vehicle Name	**Vehicle Weight, lb[1]**	**Total Length, ft[2]**	**Horsepower per Ton[3]**
M923	32,500	25.4	14.8
M923/M1061	48,350	47.1	9.3

[1] To convert pounds to kilograms, multiply by 0.4536.
[2] To convert feet to meters, multiply by 0.3048.
[3] To convert horsepower per ton to watts per kilonewton, multiply by 83.82

Table 6 shows the results for the M923 with normal visibility in a dry condition. Table 7 shows the results for the M923 towing the M1061 trailer under the same conditions.

Table 6
Capacities (Vehicles per Hour) Computed Using U.S. Army Engineer Research and Development Center (ERDC) and DIA Methodologies for a 5-ton[1] Truck

	Plains		**Hills**		**Mountains**	
Road Type	**ERDC**	**DIA**	**ERDC**	**DIA**	**ERDC**	**DIA**
Primary	1,129	600	977	480	723	360
Secondary	672	500	603	400	506	300
Trails	409	250	350	200	277	150

[1] To convert tons to kilograms, multiply by 907.1847.

Table 7
Capacities (Vehicles per Hour) Computed Using ERDC and DIA Methodologies for a 5-ton[1] Truck Towing a 5-ton Trailer

	Plains		**Hills**		**Mountains**	
Road Type	**ERDC**	**DIA**	**ERDC**	**DIA**	**ERDC**	**DIA**
Primary	773	540	668	432	524	324
Secondary	485	450	410	360	328	270
Trails	257	225	211	181	164	135

[1] To convert tons to kilograms, multiply by 907.1847.

The DIA figures are based on initial 24-hr capacities of 14,400 vehicles for Type I (primary) roads, 12,000 vehicles for Type II (secondary) roads, and 10,000 vehicles for Type III (trails) roads. The DIA capacities are further multiplied by a factor of 0.6 for trails to account for the effects of a one-lane road. The DIA capacities for plains are then multiplied by factors of 0.8 and 0.6 (road alignment factors) to account for the effects of hills and mountains on road capacity. A further factor of 0.9 is used to model the change in capacity from 5 to 10 tons[1] per vehicle in the DIA methodology. This factor is chosen because, in the DIA methodology, a factor of 1.8 is multiplied by the number of tons

[1] To convert tons to kilograms, multiply by 907.1847.

moved forward when a 10-ton truck is used instead of a 5-ton truck. Thus, 10 percent fewer 10-ton vehicles would make the trip each day as opposed to 5-ton trucks.

It is not surprising that the ERDC methodology predicts higher capacities for all vehicle and road combinations, as it is modeling a 25-vehicle column. The effects of the terrain are lessened by using a short column as the effect of segments containing steep slopes or sharp curves are not as great as when multiplied along the length of a longer column. The 25-vehicle column was chosen to represent a typical march unit, thus allowing the targeted systems to further model the effects of organizing the march units into serials (two to five march units) and then the serials into a complete march column (two to five serials).

3 API for SDDCTEA

Heterogeneous Convoys

In an effort to develop a relationship for convoys composed of vehicles of differing mobility levels, heterogeneous convoys were run over the synthetic profiles. Figure 4 shows the results of three of these runs on secondary roads in plains in a dry condition for vehicles towing trailers.

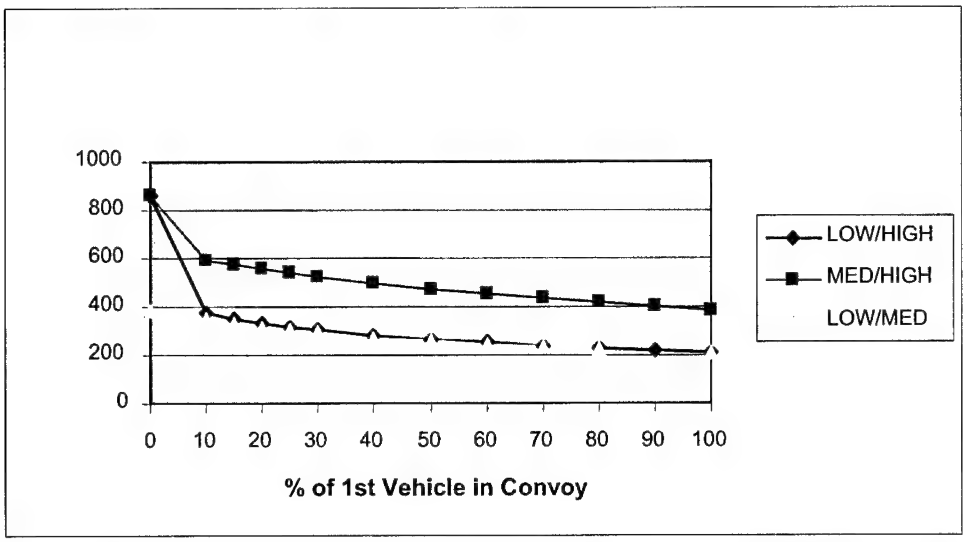

Figure 4. Example output for heterogeneous convoys

The three convoy mixes represented in Figure 4 illustrate an important concept. When the slower vehicles compose 10 percent or more of the convoy, they heavily influence the overall throughput. Thus, using the 10 percent of the vehicles composing the unit that have the lowest associated capacities will produce a conservative prediction for the throughput of the entire unit. Applying this logic to the SIB resulted in 4 percent of the capacity being governed by the low towed mobility class, 78 percent being controlled by the medium towed mobility class, and the remaining 18 percent being controlled by the high towed mobility class. For this API, only the dry-normal weather and normal visibility values for capacity in the tables in Appendix B are used. The percentages of each mobility class used to model each of the modeled units are shown in Table 8.

Table 8 Percentages of Mobility Bins for Each Unit Type					
	Mobility Bin				
Unit Type	Medium Tracked	Low Tracked	High Towed	Medium Towed	Low Towed
Separate Infantry Brigade (SIB)	0	0	43	32	25
Light Infantry Division (LID)	2	0	44	36	18
Mechanized Infantry Division (MEC)	0	18	0	48	34
Interim Brigade Combat Team (IBCT)	6	0	36	11	47
Airborne Division (ABN)	2	0	50	30	18
Air Assault Division (AAS)	3	0	2	66	29
Armor Division (ARM)	0	18	0	50	32

Capacity Modification

Next, the capacity is modified to account for lane-width restrictions. The lane-width correction factors are multiplied by the capacity derived from the table and are shown in Table 9.

Table 9 Width Correction Factors						
	Minimum Lane Width, m					
Road Type	0.0	3.6	4.6	5.5	6.4	7.2
Undivided	0.33	0.43	0.53	0.63	0.71	0.81
Divided	NA	NA	NA	1.51	1.70	1.76

These width correction factors were taken from the DIA methodology. The capacity is then multiplied by 20.0 to convert vehicles per hour to vehicles per day, as convoys are assumed to be operating 20 hr a day.

Capacity Computation for TARGET File

The API will also compute a capacity for a TARGET-generated equipment list file. The routine uses the type equipment code (TEC), the equipment nomenclature, the equipment length (inches) and the equipment weight (pounds) to classify vehicles in one of the mobility bins. The algorithm first relies on matching vehicle names to a portion of the 31-character equipment nomenclature, as there is no horsepower information in the TARGET interface records to arrive at a power-to-weight ratio. Appendix C contains tables of the vehicles that are currently stored in a data structure within the program.

If none of the listed vehicles matches the nomenclature and the TEC is a 2 or 3, the vehicle is classed as a high mobility wheeled vehicle. If the TEC is a 4 (greater than 2-1/2 tons) and the weight is greater than 33,068 lb (15,000 kg), the vehicle is classed as a medium mobility wheeled vehicle; otherwise, it is a high mobility wheeled vehicle. If the TEC is a D (tanks), E (self-propelled artillery), or C (other tracked vehicles), the vehicle is arbitrarily classed as a medium mobility tracked vehicle. Using weight seemed useless in classifying tracked vehicles because the representative vehicle for the high mobility tracked class, the M1A1, weighs over 120,000 lb (54,000 kg).

Trailers are matched to the vehicles expected to tow them. The preferred method again is by matching nomenclature. First, the routine compares the entries in a list of trailers to the equipment nomenclature. If no match is found with the trailer list, the entries in the vehicle list are compared to the equipment nomenclature (i.e., possibly the vehicle towing the trailer is mentioned in the description). If both text matches fail and the TEC is 6 (2-1/2 tons or less), the number of trailers with that equipment nomenclature will be placed in the high mobility towed class and the corresponding number of vehicles will be removed from the high mobility wheeled class. If the TEC is F (towed artillery) with a weight of less than 12,500 lb (5,700 kg), the trailers will be placed in the high mobility towed class. If the TEC is 7 (greater than 2-1/2 tons) or F (towed artillery) and the length is greater than 400 in. (10 m), or the length is greater than 300 in. (7.6 m) with a weight of more than 20,000 lb (9,000 kg), the trailers will be placed in the low mobility towed class; otherwise, they will be placed in the medium mobility towed class.

Bin Membership Procedure

The program will provide the most accurate prediction when the slower vehicles are contained in the data structure. If a vehicle is often encountered in a TARGET-generated equipment list, it should be added to the data structure. Following is the algorithm (Baylot and Gates 2002) for categorizing vehicles into the bins that best approximate a vehicle's mobility.

If the vehicle is tracked and its combat vehicle weight >500 kg, then go to step A. If the vehicle is wheeled and its combat vehicle weight >500 kg, then go to step B (otherwise it can be assumed, the vehicle is a light all-terrain vehicle (ATV) or a motorcycle and should not fall in the controlling 10 percent of the unit).

a. *Tracked Vehicles (Bins 1-3,10):*

(1) Collect, at a minimum, the following information on a tracked vehicle. If the vehicle is an amphibious combat vehicle (ACV) then place the vehicle in Bin 10.

Combat Vehicle Weight (kg)
Power (hp)
Maximum Road Speed (kph)

or

Power-to-Weight Ratio (hp/ton)
Maximum Road Speed (kph)

Note: Published Power-to-Weight Ratios do not always equal the ratio of the published Power and Combat Vehicle Weight (all multiplied by 1,000) but are close in value.

(2) Otherwise use the following equation to compute Tactical High Speed, Y_{TH} (kph).

Y_{TH} = 2.4 + 0.229* (Power-to-Weight Ratio) + 0.382 * Maximum Road Speed

or

Y_{TH} = 2.4 + 0.229* (Power)/(Combat Vehicle Weight * 0.00111) + 0.382 * Maximum Road Speed

Note: Published Power-to-Weight Ratios do not always equal the ratio of the published Power and Combat Vehicle Weight (all multiplied by 1 kg/0.00111 ton) but are close in value.

(3) Use the value of Y_{TH} to select the vehicle bin using:
Bin 1 .... $Y_{TH} \geq 31.2$
Bin 2 .... $Y_{TH} \geq 26.3$ and $Y_{TH} < 31.2$
Bin 3 .... $Y_{TH} < 26.3$

b. *Wheeled Vehicles (Bins 4-9,11):*

(1) Collect the following information on a wheeled vehicle. If the vehicle is an ACV, then place the vehicle in Bin 11.

Maximum Gradient (%)
Trailer Attached (True/False)
Combat Vehicle Weight (kg)
Power (hp)

or

Maximum Gradient (%)
Trailer Attached (True/False)
Power-to-Weight Ratio (hp/ton)

(2) If a trailer is not attached to the wheeled vehicle, then use the following equation to bin:

Y_{SS} = 1.20 + 1.258* (Power-to-Weight Ratio)+ 0.338 * Maximum Gradient

or

$Y_{SS} = 1.20 + 1.258 * (\text{Power}) / (\text{Combat Vehicle Weight} * 0.00111) + 0.338 * \text{Maximum Gradient}$

(3) Use the value of Y_{SS} to select the vehicle bin using:

Bin 4 .... $Y_{SS} \geq 42.9$ kph
Bin 5 .... $Y_{SS} \geq 38.2$ kph and $Y_{SS} < 42.9$ kph
Bin 6 .... $Y_{SS} < 38.2$ kph

(4) If a trailer is attached and the primary use is as a Heavy Equipment Transporter or the loaded Combined Vehicle Weight exceeds 60,000 kg, place the vehicle in Bin 9.

(5) Otherwise bin as follows:

Bin 7 .... Power-to-Weight Ratio ≥ 10.0
Bin 8 .... Power-to-Weight Ratio < 10.0

4 Conclusions and Recommendation

Conclusions

Based on the results of this investigation, the following conclusions can be drawn:

a. An overall methodology to represent ground vehicle movement across a theater has been developed based on the NRMMII.

b. Estimates of pass rates were generated based on readily available data for a synthetic natural environment.

c. An API was developed for use in TINet, which returns a capacity for the SIB, LID, MEC, IBCT, ABN, AAS, or ARM when given road link attributes.

d. The API was extended to read a customized TARGET output file for any Time Phased Force Deployment Data (TPFDD) or other force list of an operations plan (OPLAN) and determine throughput capacity for all the links in a highway network based on their TINet attributes.

Recommendation

Based on the information presented in this study, it is recommended to accept this API as a standard for predicting throughput capacity for seven pre-defined units or a customized TARGET output file for any TPFDD.

References

Ahlvin, R. B., and Haley, P. W. (1992). "NATO reference mobility model edition II, NRMM II user's guide," Technical Report GL-92-19, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Barnsley, M. F., Devaney, R. L., Mandelbrot, B. B., Peitgen, H., Saupe, D., Voss, R. F., Fisher, Y., and McGuire, M. (1988). *The science of fractal images*. H. Peitgen and D. Saupe, ed., Springer Verlag, New York.

Baylot, E. A., and Gates, B. Q. (2002). "Procedure for categorizing ground vehicles," Technical Report ERDC/GSL TR-02-21, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Defense Intelligence Agency. (1990). "Highway resupply methodology," Defense Intelligence Management Document DDB-2010-18-90, Washington, DC.

Headquarters, Department of the Army. (1972). "Military geographic intelligence (terrain)," FM 30-10, Washington, DC.

________. (1984). "Army motor transport, units and operations," FM 55-30, Washington, DC.

Mason, G. L., Smith, R. P., Gray, M. W., and Ahlvin, R. B. (1985). "Development of a terrain and road data base for HML transporter concepts," Technical Report GL-85-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

McKinley, G. B., Butler, C. D., Horner, D. A., Robinson, J. H., and Dickson, W. C. (1993). "Enhanced automated selection and evaluation of mobility corridors and isochrone computation," Technical Report GL-93-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Wright, P. H., and Ashford, N. J. (1982). *Transportation engineering: planning and design.* Wiley, New York.

Appendix A
Fractal Dimensions of Elevation Profiles

Profiles Selected to Represent Super Highways and Primary Roads on Plains

Profile Number	Fractal Dimension	Sigma
1	1.253	525
2	1.266	550
3	1.266	625
4	1.260	750
5	1.280	750
6	1.276	825
7	1.306	625
8	1.340	550
9	1.360	525
10	1.343	750
11	1.326	750
12	1.376	525
13	1.346	725
14	1.343	825
15	1.396	525
16	1.350	850
17	1.373	750
18	1.396	625
19	1.386	725
20	1.403	650
21	1.436	525
22	1.400	825
23	1.426	725
24	1.446	650
25	1.472	525

Profiles Selected to Represent Super Highways and Primary Roads on Hills

Profile Number	Fractal Dimension	Sigma
1	1.073	2250
2	1.093	2250
3	1.110	2250
4	1.126	3000
5	1.143	3000
6	1.163	3000
7	1.206	2250
8	1.246	1500
9	1.190	3000
10	1.193	3000
11	1.256	1800
12	1.313	1250
13	1.303	1500
14	1.260	2250
15	1.310	1500
16	1.313	1500
17	1.290	2000
18	1.343	1250
19	1.336	1500
20	1.310	2000
21	1.350	1500
22	1.416	900
23	1.326	2250
24	1.350	2250
25	1.440	1250

Profiles Selected to Represent Super Highways and Primary Roads on Mountains

Profile Number	Fractal Dimension	Sigma
1	1.143	4000
2	1.133	5000
3	1.140	5000
4	1.163	5000
5	1.193	4000
6	1.196	3500
7	1.213	3500
8	1.223	3500
9	1.210	4000
10	1.216	4000
11	1.233	3500
12	1.246	3500
13	1.260	3500
14	1.223	5000
15	1.263	3500
16	1.240	5000
17	1.253	5000
18	1.296	3500
19	1.283	4000
20	1.260	5000
21	1.290	3500
22	1.276	5000
23	1.300	5000
24	1.323	5000
25	1.356	4000

Profiles Selected to Represent Secondary Roads on Plains

Profile Number	Fractal Dimension	Sigma
1	1.356	550
2	1.330	750
3	1.320	850
4	1.336	850
5	1.330	1000
6	1.416	525
7	1.423	550
8	1.376	850
9	1.413	650
10	1.436	550
11	1.396	825
12	1.443	550
13	1.450	550
14	1.433	650
15	1.453	550
16	1.420	750
17	1.430	750
18	1.446	650
19	1.453	650
20	1.443	725
21	1.443	750
22	1.446	750
23	1.453	750
24	1.450	850
25	1.485	625

Profiles Selected to Represent Secondary Roads on Hills

Profile Number	Fractal Dimension	Sigma
1	1.346	1250
2	1.316	1800
3	1.310	2000
4	1.363	1250
5	1.300	2250
6	1.370	1250
7	1.353	1500
8	1.313	2250
9	1.316	2250
10	1.363	1500
11	1.333	2000
12	1.336	2000
13	1.390	1250
14	1.340	2000
15	1.356	1750
16	1.380	1500
17	1.436	900
18	1.406	1250
19	1.356	2000
20	1.346	2250
21	1.420	1250
22	1.426	1250
23	1.370	2250
24	1.393	2000
25	1.393	2250

Profiles Selected to Represent Secondary Roads on Mountains

Profile Number	Fractal Dimension	Sigma
1	1.216	3500
2	1.246	4000
3	1.260	3500
4	1.280	3500
5	1.270	4000
6	1.296	3500
7	1.283	4000
8	1.260	5000
9	1.303	3500
10	1.263	5000
11	1.290	4000
12	1.267	5000
13	1.293	4000
14	1.273	5000
15	1.276	5000
16	1.306	4000
17	1.326	3500
18	1.290	5000
19	1.296	5000
20	1.300	5000
21	1.343	3500
22	1.316	5000
23	1.350	4000
24	1.376	3500
25	1.346	5000

Profiles Selected to Represent Trails on Plains

Profile Number	Fractal Dimension	Sigma
1	1.430	575
2	1.450	500
3	1.430	625
4	1.453	525
5	1.443	585
6	1.446	585
7	1.436	650
8	1.396	925
9	1.453	550
10	1.420	800
11	1.430	750
12	1.456	585
13	1.416	875
14	1.420	880
15	1.416	885
16	1.423	860
17	1.420	925
18	1.456	650
19	1.443	750
20	1.426	885
21	1.440	800
22	1.450	725
23	1.436	860
24	1.456	750
25	1.456	885

Profiles Selected to Represent Trails on Hills

Profile Number	Fractal Dimension	Sigma
1	1.296	2250
2	1.366	1250
3	1.373	1250
4	1.330	1800
5	1.326	2000
6	1.320	2250
7	1.326	2250
8	1.353	1800
9	1.380	1500
10	1.340	2250
11	1.453	900
12	1.400	1500
13	1.403	1500
14	1.386	1800
15	1.376	2000
16	1.380	2000
17	1.370	2250
18	1.386	2000
19	1.376	2250
20	1.443	1250
21	1.453	1250
22	1.393	2250
23	1.413	2000
24	1.403	2250
25	1.430	2000

Profiles Selected to Represent Trails on Mountains

Profile Number	Fractal Dimension	Sigma
1	1.256	5000
2	1.306	3500
3	1.266	5000
4	1.276	5000
5	1.280	5000
6	1.326	3500
7	1.290	5000
8	1.293	5000
9	1.333	3500
10	1.296	5000
11	1.336	3500
12	1.303	5000
13	1.343	3500
14	1.346	3500
15	1.313	5000
16	1.356	3500
17	1.360	3500
18	1.323	5000
19	1.330	5000
20	1.336	5000
21	1.343	5000
22	1.346	5000
23	1.390	3500
24	1.356	5000
25	1.363	5000

Appendix B
Final Capacities

Wheeled Vehicles - High Mobility Class: M1084
Capacities, vehicles/hr

Table B1
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1128	862	564	300
	Secondary	824	792	564	300
	Trail	541	492	488	300
Wet-Slippery	Primary	1128	701	512	300
	Secondary	824	681	498	300
	Trail	405	390	357	300
Snow	Primary	1128	652	479	300
	Secondary	752	636	468	300
	Trail	705	540	400	300

Table B2
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1128	857	564	300
	Secondary	735	733	564	300
	Trail	433	414	357	300
Wet-Slippery	Primary	1128	694	507	300
	Secondary	735	669	491	300
	Trail	340	333	297	300
Snow	Primary	1041	645	473	300
	Secondary	653	625	459	300
	Trail	598	506	377	300

Table B3
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	934	846	564	300
	Secondary	612	565	560	300
	Trail	333	328	297	300
Wet-Slippery	Primary	934	679	497	300
	Secondary	612	560	476	300
	Trail	270	268	256	300
Snow	Primary	801	626	460	300
	Secondary	576	512	443	300
	Trail	427	335	311	300

Wheeled Vehicles - Medium Mobility Class: M985 Capacities, vehicles/hr

Table B4
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1085	795	542	276
	Secondary	768	745	542	276
	Trail	463	435	422	276
Wet-Slippery	Primary	1085	648	472	276
	Secondary	768	628	459	276
	Trail	381	369	351	276
Snow	Primary	1049	591	433	276
	Secondary	679	576	423	276
	Trail	326	326	326	276

Table B5
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1039	791	542	276
	Secondary	655	651	542	276
	Trail	406	392	354	276
Wet-Slippery	Primary	1039	642	468	276
	Secondary	655	618	452	276
	Trail	341	331	306	276
Snow	Primary	890	584	429	276
	Secondary	594	538	415	276
	Trail	326	326	326	276

Table B6
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	824	780	542	276
	Secondary	549	475	468	276
	Trail	333	326	296	276
Wet-Slippery	Primary	824	626	458	276
	Secondary	549	472	439	276
	Trail	268	263	248	276
Snow	Primary	746	566	416	276
	Secondary	519	452	399	276
	Trail	311	311	309	276

Wheeled Vehicles - Low Mobility Class: M917 Capacities, vehicles/hr

Table B7
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1011	696	504	288
	Secondary	617	534	493	288
	Trail	326	318	285	288
Wet-Slippery	Primary	1011	560	411	288
	Secondary	617	512	395	288
	Trail	219	218	216	288
Snow	Primary	899	505	374	288
	Secondary	564	473	361	288
	Trail	464	415	310	288

Table B8
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	894	691	501	288
	Secondary	544	468	467	289
	Trail	273	269	255	288
Wet-Slippery	Primary	864	553	407	288
	Secondary	544	467	386	289
	Trail	194	194	192	288
Snow	Primary	801	498	369	288
	Secondary	483	413	351	289
	Trail	385	311	282	288

Table B9
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	660	629	492	288
	Secondary	428	373	337	288
	Trail	222	219	214	289
Wet-Slippery	Primary	660	534	392	288
	Secondary	428	340	333	288
	Trail	152	151	150	248
Snow	Primary	593	474	352	288
	Secondary	391	314	310	288
	Trail	267	233	206	247

Tows - High Mobility Class: M1084/M1095
Capacities, vehicles/hr

Table B10
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	957	816	535	268
	Secondary	590	529	504	268
	Trail	294	295	282	268
Wet-Slippery	Primary	957	663	485	268
	Secondary	590	520	471	268
	Trail	230	231	228	268
Snow	Primary	783	616	452	268
	Secondary	522	453	435	268
	Trail	496	390	378	268

Table B11
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	799	751	535	268
	Secondary	505	454	425	268
	Trail	247	248	241	268
Wet-Slippery	Primary	799	657	480	268
	Secondary	505	426	425	268
	Trail	191	194	192	268
Snow	Primary	715	609	448	268
	Secondary	421	360	343	268
	Trail	348	294	253	268

Table B12
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	611	572	536	268
	Secondary	370	351	301	268
	Trail	193	193	191	268
Wet-Slippery	Primary	611	559	470	268
	Secondary	370	333	288	268
	Trail	136	136	135	217
Snow	Primary	567	504	435	268
	Secondary	336	307	271	268
	Trail	226	212	197	268

Tows - Medium Mobility Class: M985/M989
Capacities, vehicles/hr

Table B13
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	790	620	450	235
	Secondary	519	437	419	235
	Trail	306	299	272	235
Wet-Slippery	Primary	790	498	366	235
	Secondary	519	427	352	235
	Trail	216	214	209	235
Snow	Primary	738	463	343	235
	Secondary	484	408	332	235
	Trail	455	367	276	235

Table B14
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	740	615	445	235
	Secondary	452	392	391	235
	Trail	251	247	235	235
Wet-Slippery	Primary	740	491	362	235
	Secondary	452	391	344	235
	Trail	175	174	171	235
Snow	Primary	660	457	338	235
	Secondary	422	375	323	235
	Trail	364	282	251	235

Table B15
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	550	476	438	235
	Secondary	380	341	309	235
	Trail	185	183	179	235
Wet-Slippery	Primary	550	459	350	235
	Secondary	380	312	307	235
	Trail	124	123	122	189
Snow	Primary	510	424	324	235
	Secondary	358	298	294	235
	Trail	241	209	185	201

Tows - Low Mobility Class: M911/M747 Capacities, vehicles/hr

Table B16
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	503	469	414	209
	Secondary	268	265	241	209
	Trail	128	128	128	196
Wet-Slippery	Primary	503	434	413	209
	Secondary	268	259	240	209
	Trail	73	73	73	130
Snow	Primary	425	372	362	209
	Secondary	231	226	214	209
	Trail	197	192	185	209

Table B17
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	457	433	357	209
	Secondary	211	210	203	209
	Trail	106	106	106	168
Wet-Slippery	Primary	457	397	356	209
	Secondary	211	208	203	209
	Trail	73	73	73	130
Snow	Primary	374	335	295	209
	Secondary	190	188	184	209
	Trail	148	145	142	188

Table B18
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	317	306	261	209
	Secondary	176	175	171	209
	Trail	86	85	85	143
Wet-Slippery	Primary	317	290	260	209
	Secondary	176	174	171	209
	Trail	73	73	73	130
Snow	Primary	266	248	225	209
	Secondary	160	158	156	209
	Trail	95	94	94	145

Tracked Vehicles - High Mobility Class: M1A1
Capacities, vehicles/hr

Table B19
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1123	627	442	298
	Secondary	790	619	437	298
	Trail	621	587	458	298
Wet-Slippery	Primary	1123	519	374	298
	Secondary	790	503	364	298
	Trail	514	469	418	298
Snow	Primary	1085	505	364	298
	Secondary	772	493	356	298
	Trail	644	430	314	298

Table B20
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1044	624	441	298
	Secondary	712	613	434	298
	Trail	541	471	451	298
Wet-Slippery	Primary	1044	514	373	298
	Secondary	712	498	359	298
	Trail	462	416	410	298
Snow	Primary	1012	500	361	298
	Secondary	692	485	351	298
	Trail	572	409	301	298

Table B21
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	862	617	436	298
	Secondary	618	575	428	298
	Trail	456	393	388	298
Wet-Slippery	Primary	862	503	363	298
	Secondary	618	481	349	298
	Trail	398	346	345	298
Snow	Primary	802	487	353	298
	Secondary	606	470	341	298
	Trail	449	361	273	283

Tracked Vehicles - Medium Mobility Class: M88A1 Capacities, vehicles/hr

Table B22
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	750	732	539	295
	Secondary	472	472	461	295
	Trail	376	376	350	295
Wet-Slippery	Primary	750	732	539	295
	Secondary	472	472	461	295
	Trail	336	336	324	295
Snow	Primary	722	722	560	295
	Secondary	447	447	439	295
	Trail	391	378	350	295

Table B23
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	696	695	533	295
	Secondary	416	411	405	295
	Trail	345	345	318	295
Wet-Slippery	Primary	696	695	533	295
	Secondary	416	411	405	295
	Trail	278	278	269	295
Snow	Primary	648	648	557	295
	Secondary	404	403	381	295
	Trail	352	344	316	295

Table B24
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	501	501	489	295
	Secondary	382	378	353	295
	Trail	263	263	254	295
Wet-Slippery	Primary	501	501	489	295
	Secondary	382	378	353	295
	Trail	226	226	222	295
Snow	Primary	476	476	468	295
	Secondary	377	376	350	295
	Trail	266	262	244	295

Tracked Vehicles - Low Mobility Class: AVLB Capacities, vehicles/hr

Table B25
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	591	515	375	267
	Secondary	418	384	363	267
	Trail	315	301	286	267
Wet-Slippery	Primary	591	515	375	267
	Secondary	418	384	363	267
	Trail	264	261	248	267
Snow	Primary	558	530	385	267
	Secondary	402	368	358	267
	Trail	345	345	295	267

Table B26
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	537	508	373	267
	Secondary	375	335	334	267
	Trail	277	269	244	267
Wet-Slippery	Primary	537	508	373	267
	Secondary	375	335	334	267
	Trail	233	231	218	267
Snow	Primary	500	480	380	267
	Secondary	360	321	321	267
	Trail	294	294	250	267

Table B27
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	432	404	362	267
	Secondary	328	293	285	267
	Trail	225	221	208	267
Wet-Slippery	Primary	432	404	362	267
	Secondary	328	293	285	267
	Trail	194	193	187	267
Snow	Primary	417	387	373	267
	Secondary	317	292	277	267
	Trail	225	225	193	267

Amphibious Wheeled Vehicles: LAV3 Capacities, vehicles/hr

Table B28
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1147	609	439	310
	Secondary	829	592	428	310
	Trail	555	519	445	310
Wet-Slippery	Primary	1147	587	426	310
	Secondary	829	569	413	310
	Trail	450	430	428	310
Snow	Primary	1147	542	395	310
	Secondary	801	526	386	310
	Trail	751	455	335	310

Table B29
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	1147	603	436	310
	Secondary	769	584	422	310
	Trail	456	431	426	310
Wet-Slippery	Primary	1147	582	421	310
	Secondary	769	562	403	310
	Trail	377	338	331	310
Snow	Primary	1128	537	391	310
	Secondary	715	515	379	310
	Trail	598	427	317	310

Table B30
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	994	591	428	310
	Secondary	605	535	413	310
	Trail	382	343	329	310
Wet-Slippery	Primary	994	569	413	310
	Secondary	605	534	396	310
	Trail	311	301	272	310
Snow	Primary	842	517	380	310
	Secondary	588	491	367	310
	Trail	459	367	281	305

Amphibious Tracked Vehicles: M113A2 Capacities, vehicles/hr

Table B31
Plains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	757	727	551	335
	Secondary	634	618	541	335
	Trail	461	424	407	335
Wet-Slippery	Primary	757	680	496	335
	Secondary	634	616	481	335
	Trail	357	352	331	335
Snow	Primary	675	670	505	335
	Secondary	573	551	495	335
	Trail	536	486	416	335

Table B32
Hills

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	722	692	548	335
	Secondary	590	559	535	335
	Trail	383	368	331	335
Wet-Slippery	Primary	722	675	491	335
	Secondary	590	559	474	335
	Trail	337	334	317	335
Snow	Primary	663	649	502	335
	Secondary	518	482	483	335
	Trail	401	334	315	335

Table B33
Mountains

Scenario	Road Type	Normal	Fog	Limited	Blackout
Dry-Normal	Primary	646	637	540	335
	Secondary	441	393	353	335
	Trail	339	332	309	335
Wet-Slippery	Primary	646	636	480	335
	Secondary	441	371	351	335
	Trail	301	298	287	335
Snow	Primary	602	583	490	335
	Secondary	405	364	342	335
	Trail	329	300	278	335

Appendix C
Vehicles and Corresponding Bins

Table C1
Tracked Vehicles, Bins 1-3

Tracked Vehicle	ASCII ID	Combat Weight kg	Power to Weight Ratio hp/ton[1]	Max Road Speed kph	Vert Obs m	Power hp[2]	Pred. Y_{TH} kph	BIN
Leopard II	LEOPARD	55150	27.0	72	1.10	1641	36.3	1
M1A1	M1A	54545	27.0	72	1.24	1500	36.1	1
AMX 40 LeClerc	LECLERC	43700	30.0	70	1.00	1445	36.0	1
T80	T80	42500	25.9	70	1.00	1213	35.1	1
T64	T64	39500	17.7	75	0.80	771	35.1	1
Leopard I	LEOPARD	40000	20.8	65	1.15	915	32.0	1
M2A2	M2A	30000	18.1	66	0.91	600	31.8	1
AMX 30	AMX	36000	20.0	65	0.93	794	31.8	1
M2A1	M2A	25940	17.5	66	0.91	500	31.6	1
MarderA3 /Roland	MARDER	35000	18.0	65	1.00	600	31.4	1
M270 MLRS	MLRS	25191	18.0	64	1.00	500	31.0	2
Challenger	CHALLENGER	62000	19.4	60	0.85	1322	29.8	2
T72	T72	44500	18.9	60	0.85	927	29.6	2
GMZ Mine Layer	GMZ	28500	18.4	60	0.70	579	29.5	2
2S3 152mm SPH	2S3	27500	17.3	60	0.70	525	29.3	2
Merkava Mk 3	MERKAVA	61000	19.7	55	1.00	1323	27.9	2
M109A1B SPH	M109A1B	24948	14.7	56	0.53	405	27.3	2
T55	T55	36000	16.1	50	0.80	639	25.2	3
T69	T69	37000	15.9	50	0.80	648	25.1	3
T62 w/o Rct-Arm	T62	40000	14.5	50	0.80	639	24.8	3
T54/Type59	T54	36000	14.4	50	0.79	573	24.8	3
T55/MTU-20	T55	37000	14.2	50	0.80	580	24.8	3
M48A5	M48A5	48987	15.9	48	0.92	750	24.5	3
T55/IMR	T55	34000	15.5	48	0.80	580	24.3	3
M60A3	M60A	52617	14.2	48	0.91	750	24.1	3
Chieftain	CHIEFTAIN	55000	13.6	48	0.91	826	23.9	3
M60/AVLB	AVLB	55205	12.3	48	0.91	750	23.6	3
ZSU-23-4/SA-6	ZSU	20500	12.4	44	1.10	280	22.1	3
M88A1	M88A	50848	13.4	42	1.07	750	21.8	3
D7-G	D7-G	14456	12.6	10	1.00	200	9.1	3

[1] To convert horsepower per ton to watts per kilonewton, multiply by 83.32.
[2] To convert horsepower to watts, multiply by 745.6999.

Table C2
Wheeled Vehicles, Bins 4-6

Wheeled Vehicle	ASCII ID	Combat/ Loaded Weight kg	Power-to-Weight Ratio	Max Road Speed kph	Fording m	Max Grad %	Power hp	Pred. Y_{ss} kph	BIN
UAZ469	UAZ469	2290	29.71	100	0.70	62	75	59.7	4
M1025A2	M1025A	4672	31.07	113	0.76	40	160	53.9	4
M1043	M1043	4672	31.07	113	0.76	40	160	53.9	4
M1078	M1078	9507	21.47	94	0.81	60	225	48.7	4
M1083	M1083	13258	19.84	94	0.81	60	290	46.6	4
RB 44	RB 44	5300	18.66	109	0.75	60	109	45.1	4
GAZ-66	GAZ	5800	17.99	95	0.80	60	115	44.3	4
M1084/MTV	M1084 or MTV	15078	17.45	94	0.81	60	290	43.6	4
BAZ-135L4/FROG	BAZ	19000	17.19	65	0.58	57	360	42.2	5
ZIL 135/FROG7	ZIL 135	19000	17.19	65	0.58	57	360	42.2	5
MAN Cat I A1	MAN	32000	15.59	90	1.20	60	550	41.2	5
M923	M923	14030	15.52	84	0.76	60	240	41.2	5
M977 HEMTT	M977 or HEMTT	27080	14.91	88	0.76	60	445	40.4	5
M985 HEMTT	M985 or HEMTT	28168	14.33	88	0.76	60	445	39.7	5
MAZ543M/Scud/ SA10	MAZ543M	32470	14.60	63	1.10	57	525	38.9	5
SEE	SEE	7250	13.76	80	0.76	60	110	38.9	5
ZIL 131	ZIL 135	10425	13.05	80	1.40	58	150	37.4	6
URAL375/SA-4Reload	URAL 375	13300	12.28	75	1.00	60	180	37.1	6
RM70	RM70	25300	9.68	75	1.40	60	270	37.0	6
M35A2	M35A2	10400	12.21	90	0.76	60	140	37.0	6
M1074/PLS	M1074 or PLS	39916	11.36	91	1.22	60	500	35.9	6
KRAZ 260V	KRAZ 260V	22000	11.88	80	1.20	58	288	35.9	6
ZTS 152	ZTS 152	29250	13.74	80	1.40	60	345	35.0	6
MAZ543A	MAZ543A	43300	11.00	63	1.10	57	525	34.4	6
ZIL 157	ZIL 157	8450	11.70	65	0.85	53	109	34.0	6
KRAZ 214	KRAZ 214	19300	9.64	55	1.00	57	205	32.7	6
MK48/14	MK48	47628	8.48	84	1.52	60	445	32.3	6
TAM 150 T11	TAM 150 T11	11400	11.94	85	1.00	43	150	30.8	6
M917	M917	33070	10.97	107	0.61	41	400	29.0	6

Table C3
Wheeled Vehicles with Trailers, Bins 7-9

Wheeled Vehicle	ASCII ID	Combined Vehicle Weight kg	Power-to-Weight Ratio	Ground Clear m	Max Road Speed kph	Ford Depth m	Max Grad %	Power hp	BIN
M1025A2t	M1025A	6668	21.6	0.38	113	0.76	40	160	7
M923 w/trailer	M923	12977	16.6	0.3	84	0.76	60	240	7
M813 w/trailer	M813	18985	11.4	0.295	84	0.76	67	240	7
MTVM1094	MTV	25049	10.4	0.559	94	0.81	60	290	7
Leyland Truck (8x6)	LEYLAND	32000	9.8	0.29	75	0.75	61	350	8
M985 w/trailer	M985	42121	9.5	0.3	88	0.76	60	445	8
TATRA815	TATRA	35400	8.4	0.41	80	1.40	30	333	8
M915A2	M915A2	47670	7.6	0.254	90	0.51	18.4	400	8
M916A1	M916A1	59020	6.1	0.305	85.3	0.51	18	400	8
MAZ537 w/trailer	MAZ537	86600	5.5	0.35	50	1.30	8	525	9
Hanyang HY473A	HANYANG HY473A	62000	5.2	0.34	64	0.70	24	355	9
Mercedes Benz 3850	MERCEDES BENZ 3850	110000	4.1	0.39	85	0.70	32	500	9
M911 HET	M911 or HET	102514	4.0	0.25	72	1.07	20	450	9
FAP 3232	FAP 3232	81000	3.6	0.38	60	1.20	32	320	9

Table C4
Tracked Amphibious Combat Vehicles, Bin 10

Tracked Vehicle	ASCII ID	Combat Weight kg	Max Road Speed kph	Max Grad %	Power hp
M113A2	M113A2	11253	61	60	212
M551	M551	15830	70	60	300
2S9	2S9	9000	60	60	300
M9ACE	M9ACE	24500	48	60	295
BMP-2	BMP	14300	65	60	320
BMP-1/WZ501	BMP	13500	80	60	300
2S1 122mm SPH	2S1	16000	60	60	240
PT76	PT76	14600	44	70	240
BMP-3	BMP	18700	70	60	551
YW531H (PRC)	YW531	13600	65	60	352
BMD-3	BMD	13200	70	60	495
BMD-1	BMD	7500	70	60	265
BTR 50	BTR	14200	44	70	265
AAVP7A1	AAVP7A	22838	64	60	441
BVP M80A	BVP M80A	14000	64	66	315
MT-LB/SA-13	MT-LB	11900	62	60	264
YW531 (PRC)	YW531	12600	65	60	353
BMD-2	BMD	8225	60	60	265

Table C5
Wheeled Amphibious Combat Vehicles, Bin 11

Wheeled Vehicle	ASCII ID	Combat/ Loaded Weight kg	Ground Clear m	Max Road Speed kph	Max Grad %	Power hp
BTR70	BTR70	11500	0.48	80	60	264
BTR60P	BTR60P	9980	0.48	80	60	180
BRDM-2/ SA-9	BRDM	7000	0.43	100	60	154
LAV25	LAV	13400	0.39	100	60	303
BOV	BOV	5700	0.33	95	55	163
BTR80	BTR80	13600	0.48	90	60	286
BTR90	BTR90	17000	0.53	90	60	500
Fuchs/M93 NBC	FUCHS/M93	17000	0.41	105	70	320
LAV600	LAV	18500	0.53	100	60	298
Panhard VCR	PANHARD VCR	7900	0.38	90	60	160
SA-8	SA-8	9000	0.40	60	60	175
TAB-71	TAB-71	11000	0.47	95	60	308
TAB-77	TAB-77	13350	0.53	83	60	291
WZ 551	WZ 551	15000	0.41	85	60	282

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
September 2004

2. REPORT TYPE
Final report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Vehicle Capacity API for Transportation Infrastructure Network Builder (TINet)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
George B. McKinley

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Engineer Research and Development Center
Geotechnical and Structures Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

ERDC/GSL TR-04-11

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Military Surface Deployment and Distribution Command
Transportation Engineering Agency
720 Thimble Shoals Blvd., Ste. 130
Newport News, VA 23606-4537

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report presents the methodology and results of a process that categorizes the transportation network and the derivation of the associated pass rates for convoys of vehicles. The first part of the report describes the process of deriving the pass rates for vehicle convoys. The second part describes the development of an NT-automated protocol interface (API) to determine the highway throughput capacity (vehicles per day) of a given road link based on its Transportation Infrastructure Network Builder (TINet) attributes and the Transportation Analysis Reports Generator (TARGET) movement requirements of the force being modeled. The development effort covers these seven U.S. Army Training and Doctrine Command Table of Organization and Equipment forces: separate infantry brigade, airborne division, air assault division, light infantry division, mechanized infantry division (MEC), armor division, and Interim Brigade Combat Team. Throughput capacity as a function of road link attributes is computed for these seven hard-coded force types. The code will also compute a capacity for a TARGET-generated equipment list, which does not match one of the pre-computed seven units.

15. SUBJECT TERMS

Logistics	Road profiles	Transportation networks
Mobility	Route capacities	

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		48	